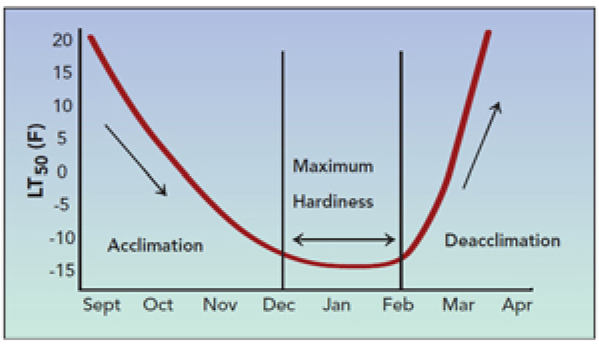
How Grapevine Buds Gain and Lose Cold-hardiness

GRAPES 101

Grapes 101 is a series of brief articles highlighting the fundamentals of cool climate grape and wine production.

By Tim Martinson



Grapevine buds gradually gain and lose cold-hardiness as temperatures fall and rise during the dormant season. (Figure from Zabadal et al., 2007)

Each fall and winter, grapevine tissues produced during the growing season transition from a cold-tender to cold-hardy state. This process, known as cold acclimation, allows vines to survive low winter temperatures. It is a gradual process, which starts around veraíson in response to low temperatures and decreasing day length and continues after leaf fall when temperatures are below freezing. As temperatures rise after mid-winter, grapevine tissues deacclimate in a gradual process, culminating in bud burst and active growth at the start of the growing season. How fast this process happens, and to what extent vine tissues survive extreme winter low temperatures, depends upon the cultivar (its genetic makeup), seasonal temperatures and how they vary, and the vine's condition as it enters the dormant season.

Dehydration and supercooling.

During the growing season, green, actively growing vine tissue is composed mostly of water–which will form ice at freezing temperatures, expanding the cells and disrupting their integrity. In preparation for the dormant season, cells become resistant to lower temperature through two mechanisms:dehydration through movement of water to intercellular spaces and accumulation of sugars and protein complexes that bind water and serve as cryoprotectants. These cryoprotectants lower the freezing point of water and allow cell contents to supercool without forming damaging ice crystals. The acclimation process starts well before freezing temperatures occur, but buds continue to gain hardiness from the onset of freezing temperatures through the coldest part of midwinter.

Dead primary bud resulting from low winter minimum temperatures.

Veraíson to leaf fall.

In autumn, green shoots turn brown from the base outwards toward shoot tips as the cork cambium forms (a ring of cells outside the phloem), producing a layer of water-resistant cork cells called the periderm. As these cells are produced and die, they become impervious to water. Buds are only weakly connected to the vine's vascular system, which isolates bud tissue and limits the potential for them to take up water. At leaf fall, buds are moderately cold-hardy and can survive temperatures ranging from 5 to 20° F.

Leaf fall to midwinter.

After the onset of below-freezing temperatures, buds continue to gain cold-hardiness through further desiccation and redistribution of water to the intercellular spaces. As ice forms outside of cells, differential vapor pressure draws water out of the cells and on to the surface of the ice crystals. This response is highly correlated with the vine's exposure to low winter temperatures. For example, buds exposed to lower winter temperatures in New York have median lethal temperatures (LT50) two to three degrees lower than buds exposed to more moderate winter temperatures in Virginia.

Midwinter to bud burst.

After attaining their maximum cold hardiness in midwinter, buds deacclimate in response to milder temperatures—and deacclimation is often more rapid than the acclimation process. Warmer temperatures increase ambient humidity, and vine tissues gradually gain water. As soils warm up, capillary action draws water up the trunk, and "sap flow" occurs. By the time of bud swell, rehydrated bud tissue is vulnerable to freeze injury at only a few degrees below freezing.

Compound buds.

Each grapevine bud contains a primary, secondary and tertiary bud. The primary bud is most well-developed and is typically less cold-hardy than secondary or tertiary buds. Freeze injury in response to low temperatures typically affects the primary bud first.

Cut buds are placed on thermocouples in a controlled-temperature freezer to determine lethal temperatures. As buds freeze they release heat, which is detected by the thermocouples.

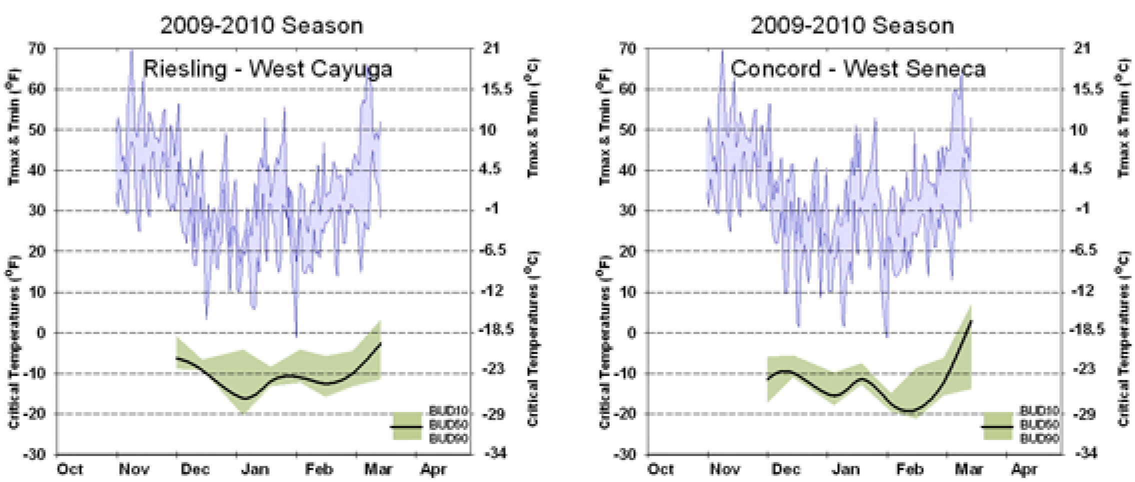
Lethal temperatures for bud injury.

We measure bud freezing temperatures by collecting canes from vineyards, cutting off buds, and placing them on thermocouples in a controlled temperature freezer. As the temperature in the freezer gradually decreases, each bud will release a small amount of heat, called a low temperature exotherm, as it freezes, allowing a precise estimate of the lethal temperature for that bud. A collection of buds from a single vineyard will exhibit a range of bud freezing temperatures that varies over two to six degrees. The median freezing temperature from a collection of 30 buds, called the LT50, is a common measure of cold hardiness. Measurements of LT50 bud freezing temperatures from leaf fall to bud burst reveal that bud hardiness undergoes constant change in response to weather conditions.

Variation among cultivars.

The winter low temperatures that injure buds limit where a cultivar can be grown. Cold-sensitive V. vinifera cultivars may have significant bud injury at <-3° F, but buds of cold-hardy varieties with V. riparia parentage can survive winter lows of -30° F. In general, cold-hardy Minnesota hybrids > Labrusca types > conventional French-American hybrids > V. vinifera cultivars. Cultivars also vary in the rate at which they acclimate and de-acclimate. Cold-hardy cultivars (e.g., Concord) may acclimate and de-acclimate faster than less cold-hardy cultivars (e.g., Cabernet Sauvignon), which occasionally can result in freeze injury in the springtime even in hardier cultivars.

Bud freezing temperatures (solid line) compared with minimum and maximum daily temperatures during the 2010-2011 winter season for Cabernet Franc (left) and Concord (right). Note that LT50 temperatures are lower and change faster for Concord than for Cabernet Franc. For current information, see [Bud Hardiness Data](#) page.



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Vine Condition.

Vine stress associated with delayed harvest, drought stress, disease pressure or overcropping can reduce the vine's ability to attain its maximum potential cold hardiness. Years in which frost is early or fruit maturity is delayed may also delay cold acclimation and reduce bud hardiness.

Consequences for management.

Genetics determines a vine's maximum cold-hardiness, but environmental conditions will influence how much of the genetic potential is realized in a given year. Growers can't influence weather conditions, but they can understand the risks, evaluate potential bud injury, and manage vines to limit or respond to bud injury in the following ways:

Cultivar selection: Match grape variety with your climate. With new cold-hardy varieties, cultivars are available that will survive even extreme winter low temperatures. If you choose more cold-sensitive varieties, be aware of the higher risk of winter injury in your climate—and be prepared to compensate for it.

Site Selection: Site your vineyard in a location that will have good air and soil drainage. Cold air moves downhill, so avoid low areas or "frost pockets" where cold air will collect. Mid-slope areas are less risky than low areas, both in midwinter and in the spring or fall. All else being equal, vineyards with heavier, more poorly drained soils will be more prone to winter injury than those on well-drained, lighter soils.

Bud injury evaluation: The extent of bud injury following a cold temperature event can be evaluated by collecting dormant canes and buds and examining them to determine whether primary buds are alive or dead. Guidelines for determining bud injury and a video for evaluating bud injury before pruning are available online.

Adjusting pruning severity: When the risk of winter bud injury has passed, it may be necessary to adjust the number of buds retained after pruning to compensate for buds lost to winter injury. Zabadal et al (2007) recommends the following:

- < 15% injury, no adjustment
- 15-35% bud mortality, retain 35% more buds
- 35-50% mortality, retain 100% more buds
- > 50% mortality, minimal or no pruning

Other protection methods: Aerial "wind machines"—powerful fans mounted on posts—can be installed in a vineyard and used during temperature inversions to mix warmer above-ground air with cold air, thus raising temperatures above bud-injuring levels at the trellis. Hilling-up soil over graft unions can protect scion buds for re-establishing trunks following a cold event that damages buds.

For further reading:

- Zabadal, T., I Dami, M Goffinet, T. Martinson, and M. Chien. 2007. Winter Injury to Grapevines and Methods of Protection. Michigan State University, Extension Bulletin E2930.

- Pool, R. M. 2000. Assessing and Responding to Winter Cold Injury to Grapevine Buds, web page, Cornell University.
- Walter-Peterson, H. 2010. Bud Injury Testing, two-part video. Finger Lakes Grape Program's YouTube channel.
- Martinson, T., S. Hoying, H. Walter-Peterson and J. Creasap Gee. Bud Hardiness Page, Viticulture and Enology Outreach page, Cornell University.

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